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Improved Beam Smoothing with SSD using Generalized Phase Modulation

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ABSTRACT

Smoothing by spectral dispersion (SSD) with standard frequency modulation (FM),[1] although very simple to implement, has the significant disadvantage that low spatial frequencies present in the spectrum of the target illumination are not smoothed as effectively as is possible with a more general smoothing method (such as the induced spatial incoherence (ISI) method).[2] This effect may have important implications for both direct and indirect drive ICF. In particular, these low spatial frequency modes are dominant for direct drive target hydrodynamics. Unfortunately, extension of the ISI method to glass lasers has been shown to significantly reduce the efficiency of high power amplification because of the poor uniformity of the near field intensity.[3]

The poor smoothing performance of standard FM-SSD at low spatial frequencies is demonstrated in Fig. 1, where it is compared to the spatial spectra obtained with the ISI-type smoothing method. At low spatial frequencies the SSD spectral power is seen to be as much

as one order of magnitude larger than that of the ISI-type method. This disadvantage of SSD can be overcome by using more general phase modulation. With such an approach one achieves optimal smoothing at low spatial frequencies and also maintains the near field beam quality (and hence the amplifer efficiency), since pure phase modulation is utilized. The essential ingredient necessary in order to achieve optimal smoothing at low spatial frequency is the generation of many "color cycles" across the beam. That is, the temporal skew across the beam imposed by the SSD grating must be many times larger than the mean period of the phase modulation. If, however, one simply uses sinusoidal FM of many color cycles, coherence resonances appear in the spatial spectrum of the target illumination owing to the pure periodicity of the FM. By generating many color cycles and also "randomizing" the phase modulation one can eliminate these resonances and still obtain optimum smoothing at low spatial frequency. As shown in Fig. 2, the spatial spectrum of the smoothed illumination of SSD using random phase modulation (RPM) of many color cycles is equivalent to that of an ISI-type method of equal divergence. Instead of RPM, a potentially simpler and more practical approach to eliminating these resonances is the use of multiple FM in series to spoil the pure periodicity of a single FM. The detailed characteristics of the different types of phase modulation necessary for adequate smoothing at low spatial frequencies will be discussed. The spatial spectra obtained with these types of generalized phase modulation will be contrasted with that of standard FM-SSD and ISI-type smoothing.

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References

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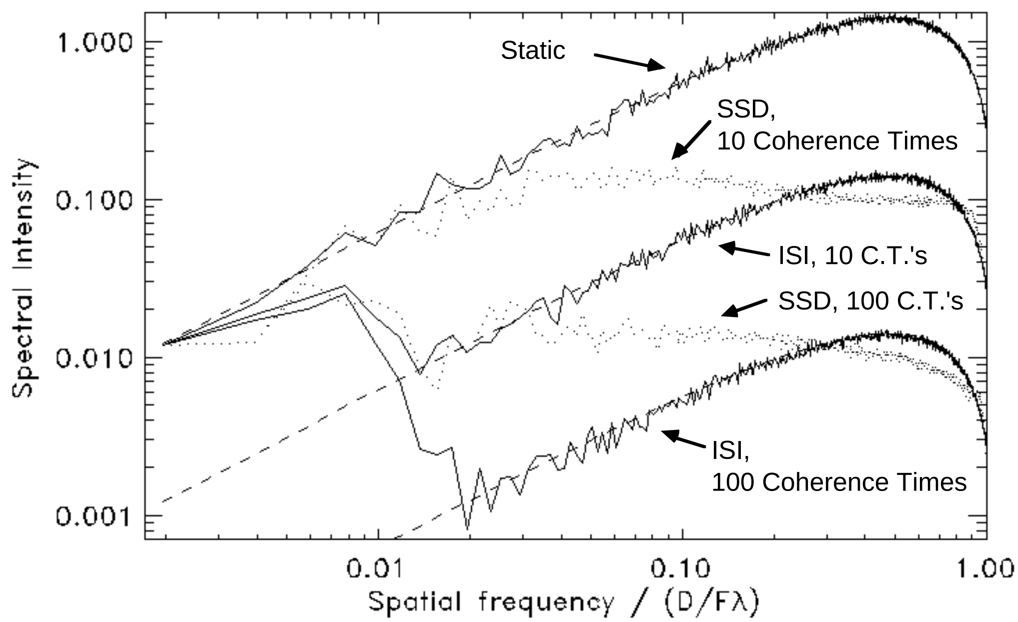

Figure 1: Comparison of calculated spatial spectra using an ISI-type smoothing method of divergence FWHM 50 λ / D (solid curves) with that of standard FM-2D SSD of equal divergence (dotted curves) for (top to bottom) the initial static speckle pattern (solid) and after an integration time equivalent to 10 and 100 coherence times. The dashed lines show the ideal ISI-type smoothing result for the case of large beam divergence. D is the beam width, F is the final focal length, and λ is the laser wavelength on target.

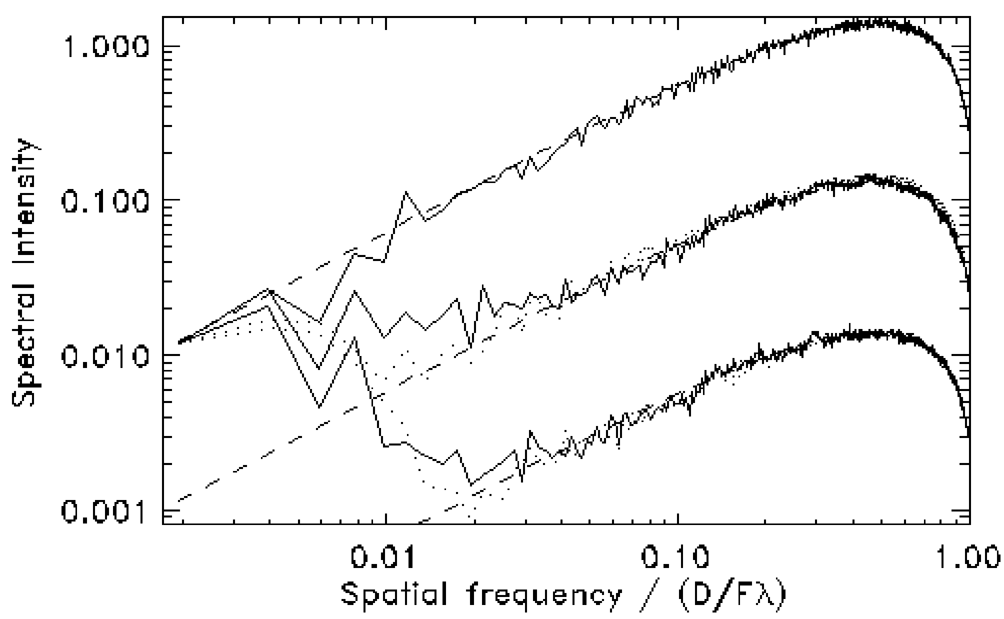

Figure 2: Comparison of calculated spatial spectra using 2D SSD with random phase modulation of ~14 color cycles across the beam (solid curves) and ISI-type smoothing (dotted curves) of equal beam divergence for (top to bottom) the initial static speckle pattern (solid) and after an integration time equivalent to 10 and 100 coherence times. The dashed curves show the ideal ISI-type smoothing result using large beam divergence.